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A BIOLOGICAL EVALUATION OF SOIL TILLING AND THE POTENTIAL FOR PEST PROBLEMS WITH CHANGING MANAGEMENT PRACTICES ON THE MILFORD RANGER DISTRICT, PLUMAS NATIONAL FOREST

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ABSTRACT

Several areas on the Milford Ranger District were examined. The possible effects of soil tillage on root pathogens and the potential for future pest problems with changing stand management practices were discussed. Because of the uncertainty of the effects of tilling on root damage and root pathogens, it was agreed that monitoring sites will be established on the District. Examples of forest pests that need to be considered with a change from even-aged to uneven-aged management are given. The potential effects of annosus root disease with increased levels of cutting in stands are discussed and a risk assessment for borax is presented.

INTRODUCTION

At the request of Dick Castaladini, Plumas National Forest Silviculturist, Forest Pest Management Pathologist John Kliejunas visited portions of the Milford Ranger District on September 1 and 2, 1992. Dick and John were accompanied by Silviculturist Al Vasquez and Culturists Peter Meyer and Tom McGrath from the District; zone (Milford/Greenville) Soil Scientist Denny Churchill; Research Pathologist Bill Otrosina from PSW, and Pathology Technician Garey Slaughter from UC-Berkeley. The objectives of the visit were to formulate possible monitoring procedures to determine the effect of tillage in residual stands on tree health, and to discuss the effects of changing stand management practices on potential future pest problems.

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The two days were spent looking at examples of recent stand management activities on the District. In particular, examples of tillage following clearcutting or precommercial thinning by mechanical harvesters (biomass harvesting) were observed, and the possible implications of new practices including tillage and management for multi-storied stands on tree health were discussed. In addition, concerns about the effect of greatly increased numbers of stumps following salvage of drought-killed true fir by biomass harvesting on the future impact of annosus root disease were raised. Basically, the Forest and the District, which are working towards forest health by thinning overstocked stands, had three questions. The questions and resulting discussions in the field follow.

OBSERVATIONS AND DISCUSSION

1. What are some of the possible effects of tillage on root disease pathogens?

The potential effects of biomass harvesting on future stand conditions were discussed at several stops. In many eastside pine areas, biomass harvesting is considered an only option to promote stand health. The stands are overstocked and need to be thinned. The use of mechanical harvesters and subsequent whole tree chipping effectively removes the fuel load from the forest floor and avoids slash which can be colonized by insects. However, compaction of the soil as a result of the equipment on the ground can be detrimental to growth of residuals, to establishment of natural regeneration in skid trails or other compacted areas, and may significantly change long-term soil productivity. Because the Forest Service is directed to carry out land management activities in a manner that does not significantly change or impair long-term productivity of the land, tillage is being used to alleviate detrimental soil compaction. A previous Forest Pest Management biological evaluation (C92-1, 1/29/92) from the Stanislaus National Forest addressed some concerns about deep tilling and resulting damage to root systems. The evaluation pointed out that tilling will probably not create root disease problems unless root disease is already on the site. In general, root disease fungi such as Heterobasidion annosum and Armillaria spp. do not exist free in the soil waiting to invade injuried roots. However, in areas where black stain root disease, caused by Leptographium wagnerii, is present in nearby stands or in the same stand, soil and root disturbance may attract root-feeding beetles that are vectors of the disease. The insect vectors are attracted to weakened and stressed trees and to freshly-created stumps. There is strong evidence that black stain incidence in Douglas-fir is associated with road building, harvesting, and other site disturbances (Hansen 1978, Harrington et al. 1983, Witcosky et al. 1986). Similarly, black stain in ponderosa pine in the central Sierra has been observed to be associated with disturbances such as logging. High incidence of black stain root disease on portions of the Devils Garden Ranger District was associated with unusual soil disruption (Kliejunas 1992).

The biological evaluation also discussed the need to consider logging damage to residual trees during harvest operations and tilling and subsequent root, butt, or heart rot, and the need to consider minimizing the number of skid trails and the enforcement of logging practices that reduce basal injury to leave trees. It was also pointed out that many questions are unanswered and that monitoring sites should be established to evaluate the impacts of tilling.

The need to establish monitoring sites to evaluate the effects of tilling was discussed at several stops on the Milford District. It was agreed that, in cooperation with the Milford District, with PSW, and with UC-Berkeley, Forest Pest Management will establish monitoring sites at various locations on the Milford District, including several within Clark's 2000.

2. What will the effect of developing multi-storied stands, in contrast to traditional clearcutting, be on potential pest problems?

As an example of new stand management strategies being developed on the Plumas National Forest, the Old Wipple Timber Sale, in an area of mostly white fir and pine, was visited on Tuesday morning. It represents an attempt to create 3 to 4-storied stands in areas that would have formerly been clearcut. Rather than clearcutting, scattered pockets of advanced regeneration were left. The area was biomass harvested, which included tree removal by mechanical harvester and chipping, followed by tilling of the soil throughout the stand to a depth of 18 to 24 inches. The area was then planted with a mixture of Douglas-fir, incense-cedar, ponderosa pine, Jeffrey pine, and some sugar pine this last Spring.

The implications of leaving the pockets of advanced regeneration on potential future pest problems were discussed. Because most of the larger residual true firs had fading tops associated with fir engraver (Scolytus ventralis) attacks, many of them would not be expected to survive for more than a few years. Many of the residual pines will not contribute to an overstory because they are infected with western dwarf mistletoe (Arceuthobium campylopodum). The plan is to girdle the trees in a few years to prevent infection of the planted ponderosa and Jeffrey pines. The girdled trees will be left for snags. Conks of H. annosum were observed in several white fir stumps. Because freshly-cut stumps were not boraxed to prevent infection by H. annosum, the root disease may develop in the stand and would be expected to cause pockets of chronic mortality. The effect of tillage on the potential for future root disease problems such as annosus or black stain is not known.

In development of or conversion to uneven-aged forests, the manager needs to have a full understanding of the insect and disease implications of implementing unevenage prescriptions and a clear objective in mind for the future stand. The incidence of and damage from some insects and pathogens will increase in uneven-aged management systems. These insects and fungi are not pests unless they interfere with management objectives. Diseases that reduce timber production are pests in stands where production of timber is the major objective. However, these same diseases may be of no consequences in stands where non-timber values are of primary concern. Examples of forest pests that will increase with uneven-aged management include dwarf mistletoes, root disease, decay fungi, blister rust, and defoliators. The manager needs to determine if the effects of these organisms in the stand will interfer with the objectives.

Levels of dwarf mistletoe will increase in multi-storied stands. With single tree or small group selection, lightly infected trees are likely to be overlooked and left, perpetuating the mistletoe in the stand. In stands comprised of susceptible trees of different sizes, the crowns of smaller trees

are continually exposed to inoculum from larger trees, resulting in infection of the upper crowns and reductions in growth (Parmeter 1978). With group selection, if the openings created are small and reforest with susceptible species, the trees in the openings will quickly become infected and will suffer heavy growth loss and mortality (Parmeter 1978, Parmeter and Scharpf 1972). The openings should be large enough to remove all infected trees, otherwise, they should be reforested with resistant or immune species. At the Old Wipple Sale for example, the planted Douglas-fir, incense-cedar, and sugar pine are resistant to western dwarf mistletoe.

Uneven-aged management of stands that have root disease present is not an attractive alternative. Infection levels as low as 5% have caused appreciable long-term yield losses. Volume yield on one modeled mixed conifer stand on the Deschutes NF with 5% initial infection by H. annosum was only 66% of that obtained from the same stand by using a clearcut harvest system (Peterson, 1989). The root disease will result in pockets of chronic mortality which may be beneficial or determinal, depending on objectives for the stand. Black stain root disease may also increase in stands with multiple entries because site disturbance attracts insect vectors of the disease (Witcosky et al. 1986).

Multiple entries will likely increase wounding of leave trees and subsequent infection by decay fungi. The fungi that cause decay in trees gain entrance in a variety of ways, but the most common is through wounds. Decay results in growth loss, tree failure, and mortality. Single tree selection results in a high degree of tree wounding because of the number of stand entries and limited room for equipment. Losses from logging wounds were as high as 14 percent of the board-foot volume in one study in California (Aho et al. 1989). Removal of large groups of trees presents lower risk of wounding trees, and thus contributes to less stem decay than single tree removal. During selection entries, cut trees should be selected on the types and numbers of decay indicators present. Guidelines for minimizing wounding of residual trees during stand entries are available (Aho et al 1983).

White pine blister rust may increase with uneven-aged management. Uneven-aged management would present a reduced opportunity for planting resistant seedlings, and the small openings created with single tree or group selection are favorable for Ribes, the alternate host for the rust. In addition to faoring Ribes, the small openings create a favorable microclimate for the fungus and infection (Kinloch and Dulitz 1990).

Damage from defoliating insects will likely increase in multi-storied stands. Multi-stories stands of the same species serve to intensify feeding and damage caused by defoliators such as budworms and tussock moths. Intermediate and understory host trees provide a suitable substrate for dispersing larvae and for build-up of the population. Even-aged stand structures are the least susceptible, two-storied intermediate, and uneven-aged are the most susceptible (Wulf and Cates 1985).

The above are examples of forest pests that need to be considered in uneven-aged management. Some treatment options are available. Forest Pest Management input is available to silviculturists and others considering the use of unevenage prescriptions, but unsure of the pest implications in their individual stands.

3. What effect will the increase in levels of salvaging drought-killed true fir have on future annosus root disease impacts, especially if borax is not used?

With no borax treatment of freshly-cut stump surfaces, annosus root disease will likely increase as salvage increases. Increased tree mortality and volume loss will result. Evidence for this is based on observations and surveys in other eastside pine and eastside mixed conifer stands in California and Oregon. If borax is used as a preventive measure, the future incidence of the disease in the stands will remain at current levels and the impact may be considerably less than if borax is not used. Some background information in support of these statements follow.

Incidence in Eastside Pine Stands

In eastside pine type forests, incidence of H. annosum is especially high and locally damaging (Wagener and Cave 1946) due to past heavy cutting of pines and an apparently favorable environment for the pathogen. Increased forest management activity has contributed to an increased incidence of annosus root disease, with the greatest losses being associated with pine stumps left after thinning and harvest cutting operations. Recent surveys (Kliejunas 1989a, 1989b, Pronos and Harris 1991) have found high levels of annosus root disease in the eastside pine type. Levels, which are based on the percentage of pine stumps examined with conks of H. annosum, were 50% on the Modoc, 10% on the Lassen, 22% on the Plumas, 14% on the Tahoe and 43% on the Inyo National Forest. Impact of the disease was especially high on the areas surveyed on the Modoc. About 20% of each acre examined is out of production. A conservative estimate is that about one fifth of the area in non-boraxed timber sales in the eastside pine type on the Modoc National Forest will not produce merchantable pines for the next 20 to 40 years.

The 22% for the Plumas National Forest was found on six sale areas cut in the late 1960s or early 1970s. The number of active centers (those with dying or recently dead pines adjacent to stumps) varied from none on three sale areas to 10 on the Dixie Sale. The average was 0.4 active centers per acre. If, as a conservative estimate, each active center is 1/10 acre in size, then about 1.1 acres of the 28 acres surveyed was out of production due to annosus root disease. This is .04 acres of each acre. Looked at in another way, the 0.4 active centers per acre, each about 0.1 acre in size, is about 4 openings, 0.1 acre in size, over 10 acres. The feeling of the silviculturists was that annosus root disease at that level was not affecting management objectives, and that in fact, it may be beneficial by creating small openings in the stand. These levels would likely increase with increased cutting and no application of borax. The numer of openings on the Modoc National Forest were 1.9 per acre, or 19 openings, each 0.1 acre in size, over 10 acres. This is about a 5 fold increase over levels on the Plumas National Forest.

Incidence in Eastside Mixed Conifer Stands

In California, incidence levels of H. annosum in eastside mixed conifer stands have not been specifically studied, but are apparently low, based on observations. In Oregon, on the other hand, numerous individual stand surveys show that mortality of 10 to 80% of the trees with 10 to 60% basal area

reduction is common (Goheen and Hagle 1988). In one specific survey of a 2,500 acre mixed conifer stand on the Sisters Ranger District, Deschutes National Forest, 19% of all trees over 5 inches dbh, representing 21.8% of the merchantable board foot volume, were killed by root disease during the previous 20 years (Filip 1980).

Factors Affecting Incidence

There is strong evidence that these existing high levels of the disease in eastside pine and eastside mixed conifer forests are largely the result of past selection harvesting, often with repeated entries in the same stand. This partial cutting left numerous infection sites in the form of freshly cut stumps. Results of a survey on two eastside National Forests in Region 6 (Schmitt and others 1984) indicated a much higher incidence of true fir infection and mortality in stands that had experienced more than one entry. The average percentage of the true firs infected and killed by H. annosum in the three stand types are presented in Table 1.

Table 1. Incidence of annosus root disease in relation to stand entry.

Type of Stand	Average Percentage	
	Ochoco	Fremont
Unentered	0	0.04
Entered Once	0.5	1.7
Multiple Entries	2.9	20.8

In surveys of true fir stands in California (Slaughter and Parmeter 1989), the single most important factor associated with annosus root disease in the stands was the presence of stumps. Disease incidence increased as the numbers of stumps from previous cuttings increased.

The above data suggests that increased cutting of true fir, without application of borax, will increase levels of annosus root disease. It must however be pointed out that the spores of H. annosum infect living tissues not colonized by saprophytes. If the stumps created are from trees that had been dead for about a year or more, infection by H. annosum will not occur.

Efficacy of Borax

Once annosus root disease becomes established in forest stands, no economically feasible procedure for directly suppressing the disease is available. Therefore, prevention is the most efficient and economical method of reducing H. annosum impact. Treatment of freshly cut pine (Graham 1971) and true fir (Smith 1970) stump surfaces with borax (sodium tetraborate decahydrate) effectively prevents infection by airborne spores of H. annosum. The borax penetrates the stumps to a depth of several inches, and remains toxic to the spores for approximately 2 years. The chemical prevents infection by preventing germination of the spores; it has no effect on existing infections.

Several surveys have indicated the benefit of boraxing pine stumps in eastside pine type stands. On three boraxed sales on the Modoc National Forest, 2 to 4% of stumps boraxed 5 to 11 years previously were infected. Adjacent sale areas of the same age where borax was not used had infection levels of 23 to 70% (Kliejunas 1989a). On the Lassen National Forest, 0 to 2% of the stumps examined in 1986 on three boraxed sales on the Lassen National Forest were infected. Pre-sale surveys in 1975 by Forest Pest Management found that 15% of stumps from previous cuttings were infected with H. annosum. Based on the assumption that, without borax treatment, about 15% of the stumps created would be infected, the decision was made to borax. About 10 years after borax treatment, only 2% of the boraxed stumps were infected (Kliejunas 1989a).

The efficacy of treating true fir stumps with borax to prevent future impact of the disease in a stand is less certain. Although borax does reduce stump infection, one study (Schultz et al 1992) indicated no differences in tree mortality between paired treated and untreated plots in 10 true fir stands 10 years after treatment. In addition, borax treatment of true fir stump surfaces will not prevent the entrance of H. annosum into the root systems of true fir stumps or entrance by other means, nor will it eradicate existing root or stump infections present at the time the tree was cut. The pathogen can enter true fir through logging wounds, and fire scars, and true fir are often infected with the fungus before stand entry. The effect of the presence of extremely large numbers of stumps following planned salvage operations is not known, but infection levels would be expected to increase with an increase in suitable substrate for infection.

Stump Diameter and Infection

Policy regarding lower limits of stump diameter to treat with borax varies by forest and district, depending largely on historical information, current observations, and other considerations. In a survey on the Hat Creek Ranger District, Lassen National Forest (DeNitto 1985), only 8 of 83 mortality spots checked did not have stumps greater than 18 inches in diameter as an apparent source of infection. The present policy on the Lassen National Forest in eastside pine type stands is to use borax on all commercial timber sales. Borax is not used in precommercial thinnings, except in those that are mechanically sheared. The survey results support that policy.

Stump diameters were measured during a survey on the McCloud Ranger District, Shasta-Trinity National Forests (DeNitto 1988). Results suggested that stumps less than 14 inches in diameter will not support active annosus infection centers. A survey (Kliejunas 1986) on the Modoc National Forest gave similar results. Stumps less than 18 inches in diameter were not infected. Surveys (Kliejunas 1989) on the Plumas and Tahoe National Forests found only 2 of 173 pine stumps less than 18 inches in diameter with conks.

Borax Recommendations

Treatment of all conifer stumps in recreation sites is directed (FSM 2305.14, R-5 Supplement 164). The same direction should apply to other high value areas, such as progeny test sites or seed orchards, as well. In timber stands, sufficient efficacy information is available to recommend borax treatment of pine stumps, about 12 inches or greater in diameter. The use of borax is

especially recommended in areas where surveys have historically indicated high levels of annosus root disease.

Borax treatment of freshly-cut true fir stumps effectively reduces the infection of stump surfaces. However, the efficacy of this treatment is less certain in true fir than in pine because H. annosum can enter true fir root systems through wounds as well as stump surfaces, and above ground crown symptoms indicating current levels of the fungus in the stand are lacking. For these reasons, the decision to treat true fir stumps in timber stands with borax should lie with the appropriate line officer who has been fully briefed on the specific situation in the particular stand in question. This briefing may be in the form of a Forest Pest Managment biological evaluation or an on-site visit.

The decision as to what lower pine or true fir stump diameter limit to treat with borax should be based on the risk the forest or district is willing to take versus the cost of the borax treatment. The recommended 12 inch lower limit is based on field observations only rarely indicating H. annosum spreading from smaller diameter, chain saw-created, pine stumps and causing active annosus root disease centers. When thinning by mechanical shearing, which may create stumps at ground level often covered by duff, the risk of infection may be greater. Stump colonization, but not active annosus centers, have been observed in stands thinned by mechanical shearing. However, since the oldest sheared stands in the eastside pine type are only about 10 years old, active centers may not have had time to develop. Until more information is available, the decision as to the lower limit at which to treat sheared stumps should be weighted toward the 8-inch limit indicated by research results (Smith, unpublished).

Borax Risk Assessment

Borax (sodium tetraborate decahydrate) is a registered pesticide (EPA Reg. No. 1624-94), and must be used according to label directions. The label and the Material Safety Data Sheet (see Appendix) contain information on the proper use and on the relative toxicity. Borax treatment on the Plumas National Forest would require a Pesticide Use Proposal approved by the Forest Supervisor.

For prevention of annosus root disease, borax is applied to freshly-cut stump surfaces at a rate of one pound per 50 square feet of stump surface. This is equivalent to one pound of borax on 60 twelve-inch stumps. The borax is diffused rapidly into freshly cut stumps to a depth of about 5 centimeters, in quantities sufficient to protect the surface from infection by H. annosum. Although some borax leaches from the stump surface, an appreciable amount remains at the 1.2 cm depth 30 months after treatment (Koenigs 1971). Some formulations of borax are registered for and used as herbicides for most noxious weeds and grasses. For these decahydrate formulations, recommended rates of dry ground applications by hand or mechanical spreaders is 9 to 15 pounds per 100 square feet (Phelps et al. undated), or 18 to 30 times the amount recommended for application to stump surfaces.

In terms of human risk, borax has an acute oral LD_{50} (rats) of 6.13g/kg, an acute dermal LD_{50} (rabbits) of greater than 10g/kg, and although non-irratating to skin or eyes, may cause slight nasal irritation on inhalation as a nuisance dust. Borax is not a carcinogen. The signal word on the borax

label is "Caution", which is equivalent to EPA toxicity category 3, or slightly toxic (LD_{50} 5,000 to 14,999 mg/kg). The chemical is considered a non-hazardous waste and has been used for years as an additive to laundary detergents.

In terms of environmental effects, borax is relatively benign. It has a low toxicity to fish and wildlife (24 hour LC_{50} for rainbow trout to borax is 2800 ppm), and is considered to have small or non-existant effects on various soil organisms. An LC_{50} greater than 100 ppm is considered practically non-toxic to freshwater fish (Zucker 1985), and a LD_{50} greater than 2,000 ppm is practically non-toxic to mammals (Farringer 1985). This information is consistent with the use of borax for washing clothes. Borax persists in the soil for one or more years depending on soil types and rainfall, with persistance decreasing in acid soils and high rainfall. The decahydrate may not persist beyond one growing season in areas of 35 inches or greater precipitation. Microbial activity probably accounts for the major breakdown of the chemical in soil (Phelps et al. undated).

Following procedures used in estimating herbicide doses to deer and rabbits (Vegetation Management FEIS, Appendix F, F-85) resulting from normal forest applications, maximum doses of borax are estimated to be 17.9 mg/kg for deer and 42 mg/kg for rabbits. This estimate is based on a broadcast application of 10 lbs/acre. Actual doses resulting from stump treatment would be expected to be orders of magnitude lower. Using the same procedures for fish and wildlife, broadcast application (not application directly to stumps) of 10 lbs/acre would result in 100 ppb in water. This would give a Q-value of 100 ppb/2800 ppm, or .00004. According to EPA criteria (1986), if the Q-value is less than 0.1, there is no acute toxicity.

The above data suggests that the proper use of borax to prevent annosus root disease poses a very low risk of adverse human or environmental effects. The application rates to stump surfaces (1 pound per 50 sq. ft. of stump surface) are much lower than rates for herbicide use (9 to 15 pounds per 100 square feet of soil). Furthermore, most of the borax applied to stumps diffuses quickly into the stump and is not available for leaching into the ground surrounding the stump.

A calculation of the amount of borax placed in the environment for annosus root disease control (Bill Merrihew, person communication) is presented in Table 2. These numbers, which are only rough averages and would vary from stand to stand, suggest that about 10 pounds of borax would be applied per acre, per 100 years. This is equivalent to 0.00023 pounds/square foot (10 pounds/acre divided by 43,560 sq. ft.).

Table 2. Borax treatment at one pound per 50 square feet of cut stump.

Year	Type of Stand	Cut Stems/Acre[1]	DBH	Ft2	lbs Borax
0	original			184/50	3.7
20	PCT	200	5	27/50	0.5
70	CT	30	13	28/50	0.6
90	CT	30	15	37/50	0.7
100	final harvest	70	18	124/50	2.5
Total					8.0

[1] Technical Bulletin 630; ponderosa pine, site index 70 and age 200

Conclusions

Sufficient information exists from observations, surveys, and knowledge of H. annosum biology in eastside pine and eastside mixed conifer forests to state that the incidence of annosus root disease increases as the number of stand entries increase. The effectiveness of borax application to freshly cut stumps as a preventive measure is also documented. Based on the above statements and observations on portions of the Plumas National Forest, boraxing of pine and true fir stumps about 12 inches or larger in diameter would prevent H. annosum from increasing in the stands, and is recommended. The manager needs to weigh the benefits of using borax versus the risks of no use in relation to management objectives and the potential impact of the disease on these management objectives.

Effective annosus root disease management reduces resource losses to levels which are economically, aesthetically, and environmentally acceptable when measured against the objecives of the forest manager. The impact of the increased incidence of H. annosum that will result if borax is not used will vary with management objectives. For example, the impact will be greater if the objectives are to maintain timber production or site productivity. The impacts may be less if the objectives are noncommodity outputs, where openings in the stand and chronic mortality may be more tolerable, if not desirable. The long term consequences of boraxing or not boraxing now will also influence management options available to the manager in the future. Once damaging levels of H. annosum are present in a stand, management options available become very limited. Borax works effectively to prevent stump infection and it is relatively easy to apply, safe, and inexpensive. The alternatives available to deal with annosus root disease once it is established are expensive, very disruptive to the site, and generally questionable as far as effectiveness.

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